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ECEN350

DC Output Power Supply with Current Limit

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Introduction

For this project, I calculated component values and constructed a fixed DC output power supply with built-in overload protection. The power supply is capable of operating from either an AC or DC input source and provides a stable output voltage with minimal ripple. A current limit feature was implemented to prevent excessive power dissipation in the output MOSFET, ensuring safe operation under fault conditions. The design includes a power indicator LED and uses a custom 2-layer PCB to neatly organize components and facilitate testing. Key features of the power supply are summarized below:

- AC or DC powered
- Resulting DC Output Voltage: 9V
- Current Limit value for overload protection: 183mA
- LED Power On indicator

Theory of Operation

This section explains the operation of the regulated DC power supply circuit shown in Figure 1.

Diodes D1 and D2 form a full-wave rectifier that converts the AC input into a pulsating DC signal. The 1000 μF capacitor Cf smooths this pulsating signal to create a more stable DC voltage at the node labeled Vfiltered, which is used as the input to the rest of the power supply circuitry.

LED D3, Rbias1, and Zener diode DZ1 work together to provide a visual power-on indication and a stable voltage reference. The current through Rbias1 is shared between the Zener diode and the LED. DZ1, a 12 V Zener, clamps the voltage and provides a regulated 12 V reference, while D3 lights up to indicate power is applied to the circuit.

The LM385 is a precision 2.5 V voltage reference diode. This reference voltage is fed into the inverting input of op-amp U1-A. A voltage divider composed of R1 and Rf sets the gain of the op-amp to produce a higher regulated output voltage. The output of U1-A (labeled Vref) serves as a feedback control voltage that sets the desired output level of the power supply.

Current limiting is achieved using R5 and Q1, a standard NPN transistor. As the load current increases, the voltage drop across R5 rises. When this voltage exceeds approximately 0.6–0.7 V (the base-emitter threshold of Q1), Q1 begins to conduct, pulling current away from the gate of M1, reducing the gate voltage and thus limiting the current through the MOSFET. By selecting R5 appropriately, the current limit can be set close to the MOSFET's safe operating region.

Voltage regulation is achieved through op-amp U1-B and MOSFET M1. The op-amp compares Vref with a portion of the output voltage sampled through the resistor divider. If the output voltage drops, U1-B increases the gate voltage on M1, allowing more current to flow and raise the output voltage. If the output voltage rises, the op-amp reduces the gate voltage, decreasing current flow. This feedback loop keeps the output voltage steady under varying load conditions.

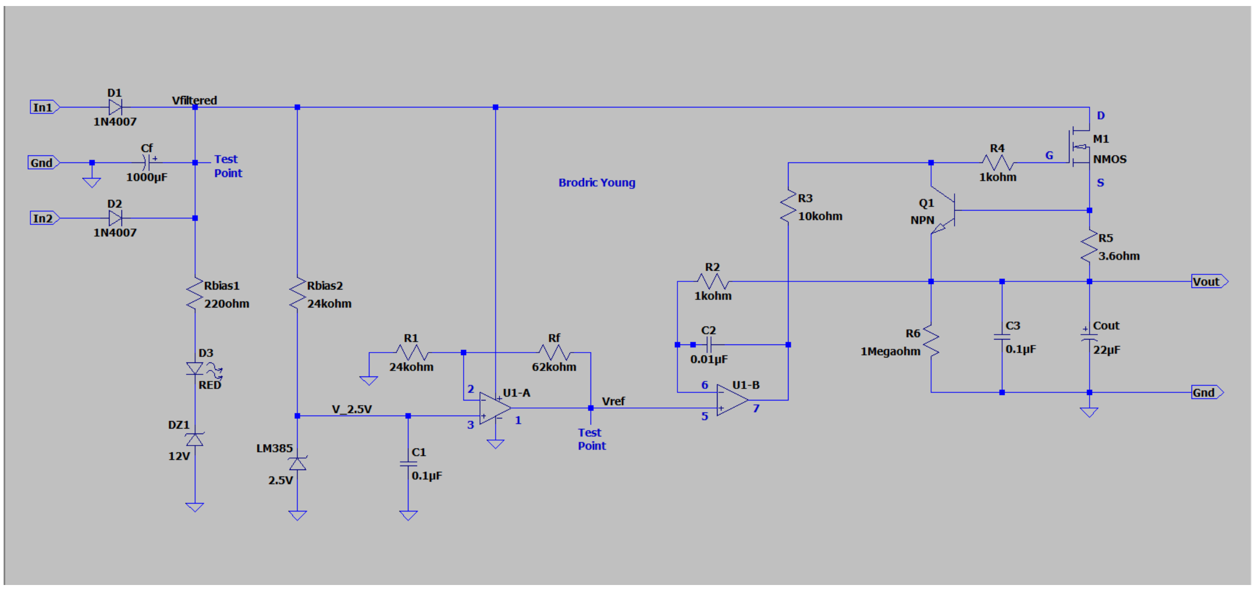

Figure 1: Schematic Diagram of the DC Output Power Supply.

Measured Performance

This section presents the results obtained from testing the assembled DC power supply. This includes key performance metrics such as the output voltage regulation across varying load currents, the effectiveness of the current limiting circuit, and the power supply's ability to reject ripple at higher load conditions. Supporting figures and tables provide a detailed comparison between theoretical calculations and real-world measurements, ensuring the design meets the intended specifications. Data was gathered using the VirtualBench oscilloscope to validate the supply's ripple rejection at approximately 90% of the calculated current limit.

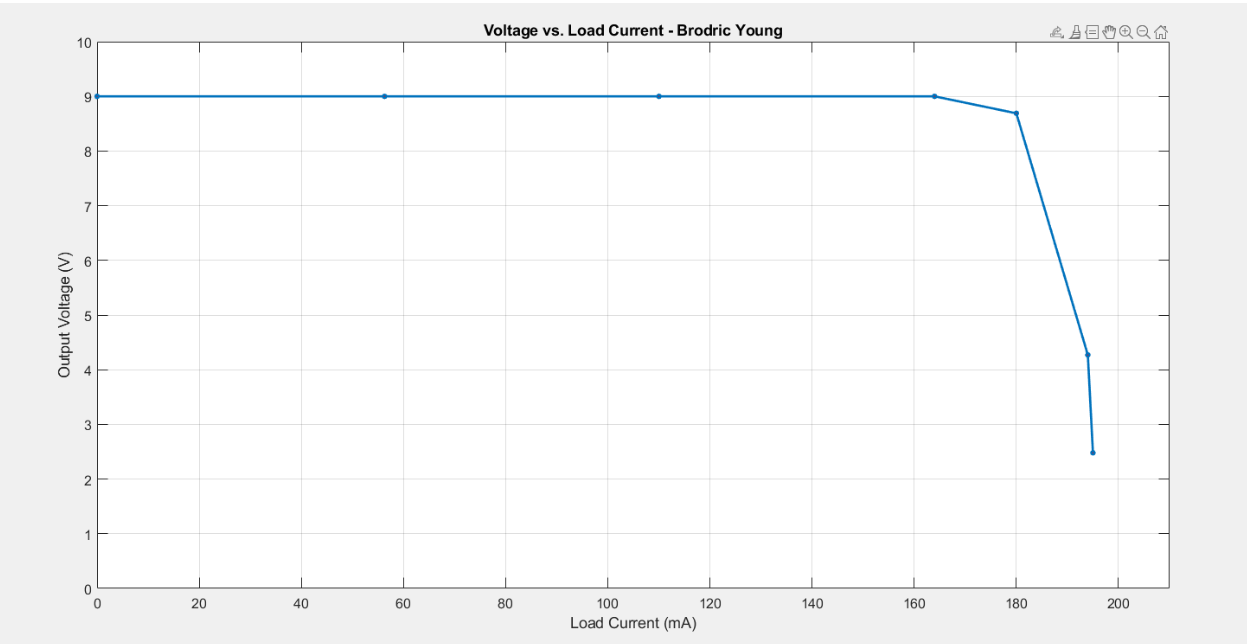

Figure 2: Output Voltage Regulation and Current Limit Graph.

Parameter	Measured Values
Minimum DC Input Voltage that turns on the LED Indicator.	13.6 V
Measured Current Limit Value I_{meas}.	195 mA
Percent error between measured and calculated current limit value, with % Error = $(100)(I_{meas} - I_{calc})/(I_{calc})$.	6.6%
Calculated input voltage ripple for $I_{Load} = 0.9I_{calc}$.	1.38 V pk-pk
Measured input voltage ripple (ΔVfiltered) for $I_{Load} \approx 0.9I_{calc}$.	2.55 V pk-pk
Measured output voltage for no external load.	9 V
Measured output voltage for $I_{Load} = 0.9I_{calc}$.	9 V
120 Hz Ripple Rejection in dB for $I_{Load} = 0.9I_{calc}$.	34 dB

Table 1: Measured Voltage regulator Performance Parameters.

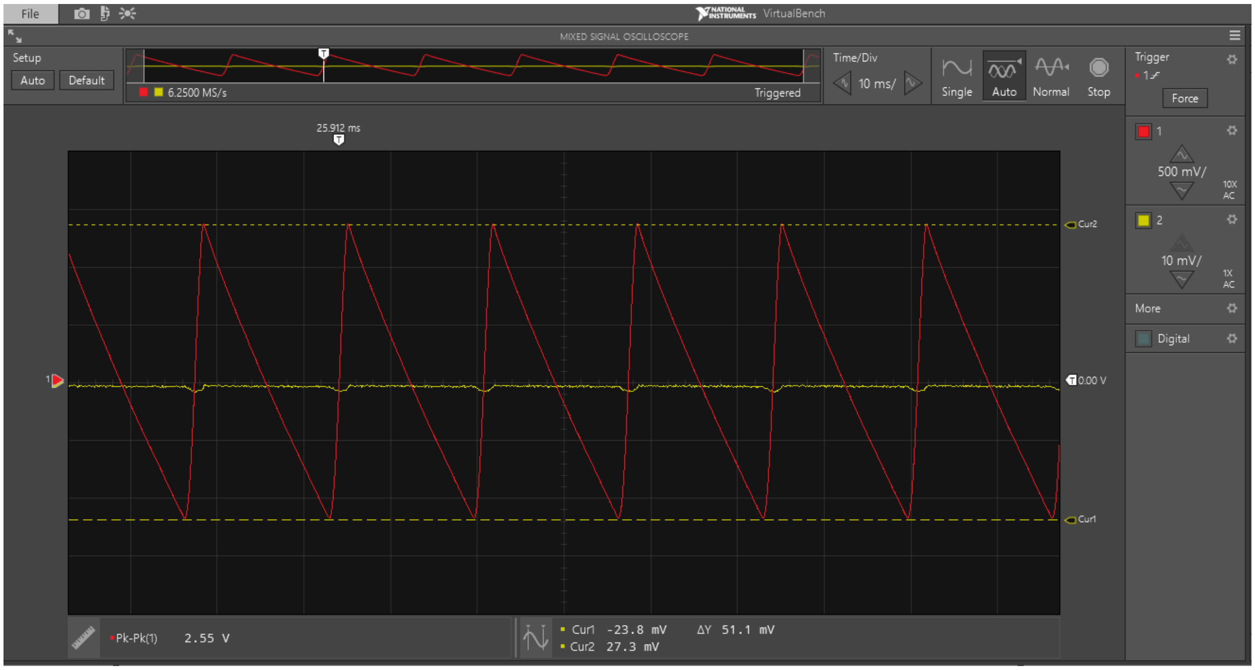

Figure 3: Output Voltage Ripple Measurement of a DC Output Power Supply. Cursors Set to Measure ΔV_{out} on Channel 2 (Yellow), resulting in $\Delta Y = \Delta V_{out} = 51.1$ mV pk-pk. Noise Reduced on Channel 2 (Yellow) by Averaging 128 Measurements.

Discussion and Conclusions

The DC Output Power Supply project successfully met its design goals of providing a fixed output voltage with effective current limiting, ripple rejection, and reliable performance under varying load conditions. Figure 4 shows the fully assembled power supply constructed on the custom two-layer PCB. This final build includes all required components, securely mounted and tested.

Simulation of the circuit in LTspice provided a valuable reference point for predicting expected behavior, particularly for setting the desired output voltage and designing the current limiting mechanism using R5 and Q1. Once constructed, the supply performed as expected, and measurements closely matched theoretical predictions given the available components in the lab, confirming the design's validity.

One important lesson learned during this project was the critical role of careful layout and verification before soldering and powering the circuit. Minor mistakes in resistor placement or value or orientation of diodes could result in failure or damaged components during the tests. Future improvements could include adding user-adjustable output voltage, over-temperature protection, or compact enclosure integration to improve both safety and user experience. Overall, this project reinforced key analog design principles and gave hands-on experience with power supply design and performance characterization.

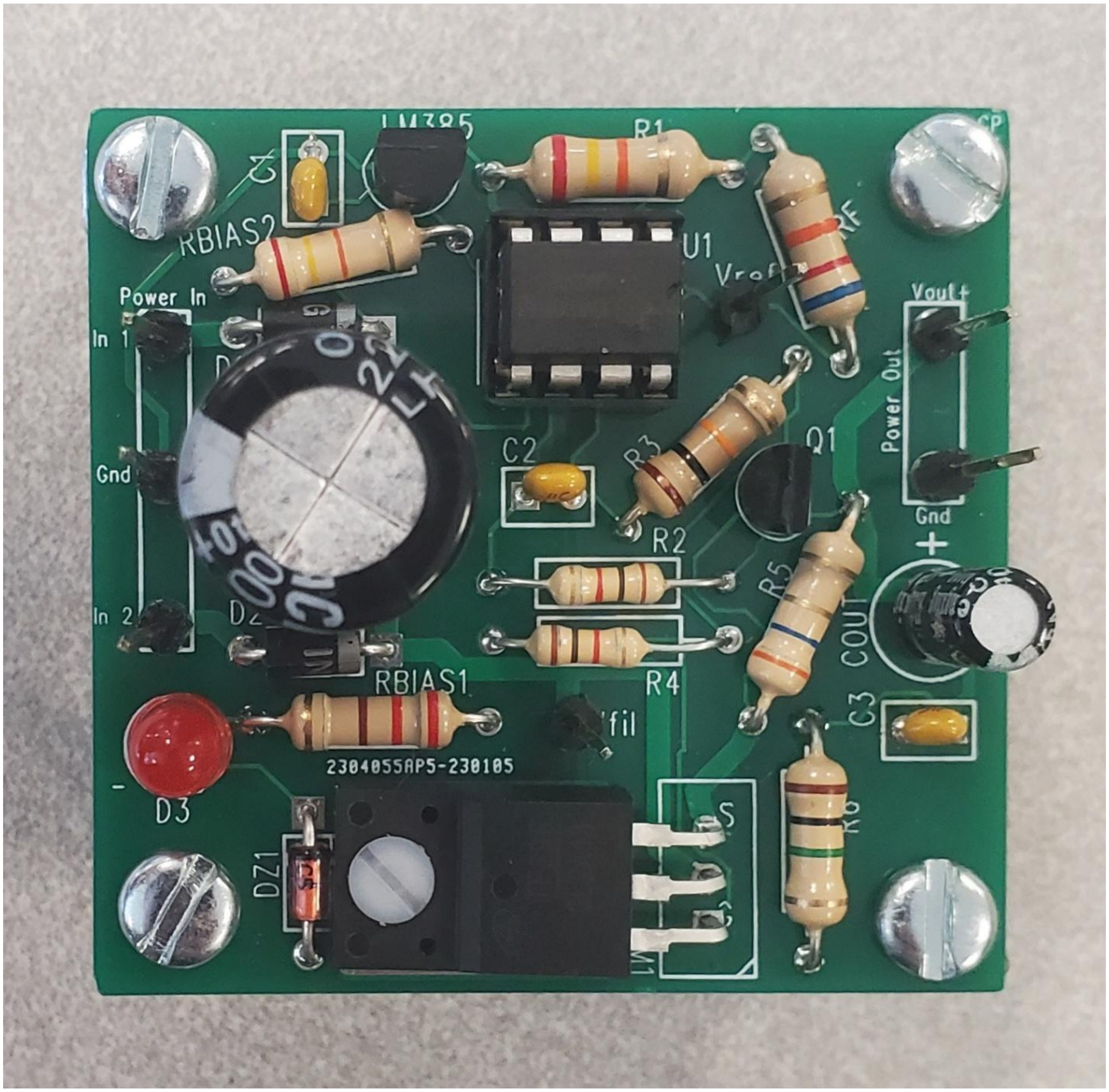

Figure 4: Completed DC Output Power Supply built on custom PCB with all components mounted and tested.